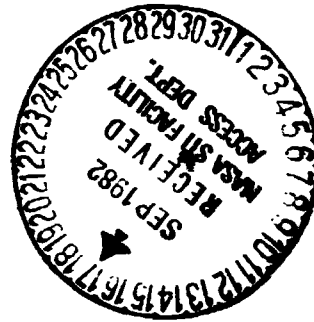


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16. ABSTRACT <p>March 22, 1982, at 11:00 a.m. Eastern Standard Time (EST), the third launch of the United States Space Shuttle (STS-3) took place. During the reentry phase of the two Solid Rocket Boosters (SRBs), one 115-ft diameter main parachute failed on the right-hand SRB (A12). This parachute failure caused the SRB to impact the ocean at 110 ft/sec in lieu of the expected "3 parachute" impact velocity of 88 ft/sec. This higher impact velocity relates directly to more SRB aft skirt and more motor case damage. A parachute failure team was formed to assess the cause of the parachute failure, the potential risks of losing an SRB as a result of this failure, and to recommend fixes to ensure that the probability of chute failures of this type in the future will be low. The team's members were from Marshall Space Flight Center, the parachute subsystem contractor, and industry-recognized parachute experts from Sandia Laboratories.</p>			
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TECHNICAL MEMORANDUM

STS-3 MAIN PARACHUTE FAILURE

On March 22, 1982, the third launch of the Space Shuttle (STS-3) occurred at 11 a.m. EST. The nose cap ejection and drogue parachute deployment phase of the Decelerator Subsystem for both Solid Rocket Booster (SRB) reentries functioned normally. Three main parachutes were observed on A11 (left-hand SRB), but only two inflated main parachutes were noted on A12 (right-hand SRB). As a result of this anomaly, A12 impacted the ocean at 110 ft/sec instead of the nominal 89 ± 6 ft/sec experienced with three main parachutes.

The Lead Retrieval Vessel (UTC Liberty) retrieved two main parachutes, one drogue, one frustum, one SRB (A12), and an assortment of main parachute flotation debris. The UTC Freedom retrieved three main parachutes, one drogue, one frustum, and one SRB. Since all main parachutes are released at SRB water impact, it is the general consensus that the missing main parachute from A12 (main chute No. 1, Serial No. 2065) must have sunk due to loss of canopy flotation. Pieces of this flotation were retrieved in the general impact area by the UTC Liberty. The failed parachute (main chute No. 2, Serial No. 2067) did not detach from the SRB even though the separation nuts had fired. This turned out to be advantageous because the flotation was missing and the parachute would have sunk had the parachute separated from the SRB at water impact.

An STS-3 parachute anomaly team was formed to determine the cause of the parachute failure and to recommend any design changes required to reduce the possibility of parachute failure on future Space Shuttle launches. A list of the parachute anomaly team members is shown in Table 1. Members of the team met at Kennedy Space Center, Florida, on March 29 through 31, 1982, to inspect STS-3 retrieved parachute hardware.

The objectives of the team were to perform a failure analysis for main parachute, Serial No. 2067, to identify the most probable failure scenario, to identify the potential risks to future mission recovery requirements, e.g., how close was a main parachute separation nut failure on one or both of the two remaining parachutes (the main parachute separation nut is the "weak link" in the parachute structural attachment to the SRB and is aggravated by higher loads resulting from a main parachute out), and to identify any corrective actions that might be incorporated on STS-4 and subs to reduce or remove these risks.

The team had a good data base, shown in Figure 1, from which to gather inputs to form and support their conclusions. It was fortunate that the Vandenberg (SRB tracking ship) locked onto the A12; because, if it were not for the film data, it would have been difficult to reconstruct a failure sequence, and it would have been practically impossible to have defended any team failure scenario position because of the lack of positive proof.

The first step in defining the cause of failure was to determine if any abnormal loads were experienced by the failed parachute. Figure 2 was generated using on-board flight recorded data. At the time of failure, the 111 kip load (approximately 2.5 sec after line stretch) on main chute No. 2 (Serial No. 2067) was within the

predicted load range for first stage inflation and well below the 174 kip design limit load. After the failure, the total load, normally distributed between three chutes, had to be shared by the two remaining chutes. Thus, the second and third stage loads on A12 are high with main chute No. 3 (Serial No. 2066) experiencing a second stage load of 235 kips, 35 percent above the design limit load. Even with this overload, however, no additional main parachute failures resulted.

As can be seen, the A11 drogue parachute experienced higher loads on every stage than the A12. A11 drogue saw a peak load of 302 kips on the full open stage (drogue design limit load is 270 kips). The three A11 main parachutes (Serial No. 2062, 2063, and 2064) saw nominal loads.

Main parachute No. 3 (Serial No. 2066) saw a load of 235 kips on the second stage of reefing. The main parachute design limit load is 174 kips.

To ascertain the greatest amount of information in the most efficient manner, specific areas of responsibility were assigned to specific team members. These task assignments are shown in Table 2. Some of these task assignments culminated in short essays or reports [1] while others required computer programs, film analysis, or testing and as such, required longer "dead lines," e.g., materials certification required pull testing to verify material strengths. This required that specific specimens be removed from canopy 2067 which require several man-hours to accomplish. Materials and Processes Laboratory had the responsibility for this effort. Their test results are shown in Reference 2.

In an effort to familiarize all team members with the packed geometry of the main parachutes and to gain a cursory understanding of the deployment process of the mains, a series of charts were prepared (Figs. 3, 4, and 5). Figure 3 shows a side view of the packed main parachute inside its bag, fastened into the isogrid structure. It shows the three separate areas inside the bag, the float area (at the top), the canopy area, and the suspension system area (dispersion bridles and risers). The figure also shows the canopy compartment flaps, the lower loop on the float system that attaches the energy absorber to the canopy apex, and the upper loop or connector strap that attaches the other end of the float energy absorber to the flat bridle.

Figure 4 depicts an idealized deployment sequence of the main parachutes from the frustum as it is pulled away from the SRB by the drogue parachute. It shows a "lines first" deployment, e.g., the risers are the first elements out of the deployment bag, then the dispersion bridles, then the suspension lines, followed by the parachute canopy, and lastly the main parachute flotation system. It should be noted that when the floats are clear of the frustum, the frustum has separated approximately 250 ft from the SRB.

Figure 5 is a closeup view of the relative locations of the lower portion of the main parachute bag and the internal structure of the frustum. It shows that the bottom of the main parachute bag is 30 to 34 in. above the separation plane (Station 398) of the frustum. Ideally, the main parachute would deploy out of the bottom of the bag in a straight down fashion and not strike any of the frustum internal structure. However, Figure 5 shows that the parachute would only have to drift 30 deg sideways or conversely; the frustum would only have to tilt 30 deg to have contact with the parachute as it is deployed out of the bag. Parachute/frustum structure contact is very undesirable because the rapidly deploying nylon fabric (300 to 350 ft/sec) will melt due to frictional heat and its strength is then degraded.

Figure 5 shows the location of a hole found in the outer bag flap. This hole is believed to have been caused by the abrasion of the bag flap against the frustum structural ring at Station 381. This ring has a relatively sharp corner and, as such, is a hazard to nylon fabric.

After reviewing the 70mm 120-in. film from the tracking ship USS Vandenberg, a frustum skewing phenomena was observed during the main parachute deployment process. Dr. Dean Wolf of Sandia Laboratories determined that this frustum skewing could be caused by wake turbulence overtake. He had coauthored a paper presented to the 7th Aerodynamic Decelerator and Balloon Technology Conference October 21-23, 1981 [3]. That discussed the wake turbulence overtake phenomena. This violent action on the drogue parachute canopy forces it sideways, and the drogue suspension lines then pull the top of the frustum sideways, thereby causing a rotation of the frustum. Figure 6 shows the frustum rotational angle at main parachute line stretch and at main parachute apex and float extraction 0.3 sec later. The angles shown were measured from a couple of frames of the 70mm film. It can be seen that the measured 30 deg would be sufficient to prove frustum/main parachute contact. It is concluded that the large skew angle of the frustum at the time of main parachute float extraction was the initial cause of the parachute damage that was observed on canopy 2067. The floats probably struck or hung up on the frustum structure during the extraction process. Further analysis of the 70mm film showed that the floats were flailing around violently immediately after deployment and became entangled with the floats from an adjacent parachute (Serial No. 2065). This entanglement induced large asymmetrical loads into the vent lines. Vent line No. 51 finally failed. The sudden stored energy release caused the stretched vent line/radial (No. 3) to snap back. This recoiling vent line sheared the vent band at the radial No. 3 joint. There was sufficient energy left in the radial to continue shearing the top 30 to 40 horizontals between radials 3 and 4. Of the remaining 200 horizontals down to the skirt, all but the 13 bottom horizontals were failed by the strain action of the No. 3 radial. Figure 7 shows the relative positioning of the three main parachutes on A12 and the damage sustained by No. 2067 in the apex area of the canopy. Figure 8 shows a more detailed damage assessment of canopy 2067. It can be deduced from this view how the floats (entangled with adjacent canopy flotation) could have caused the observed damage pattern.

To perform a complete materials evaluation, the initial action was to verify that the materials used in the failed parachute canopy were not substandard materials and were consistent with traced design military specification requirements. To achieve this, the Serial No. 2067 materials were traced back to their purchase order number at Pioneer Parachute Company and their apparent strengths from the lot sample load tests that are conducted on all material buys. A bonus from this investigation was that canopy 2066 (loaded to 235 kips) was found to have been fabricated from the same material lot buys. Table 3 shows the material and fabrication history of the failed parachute (canopy 2067). This data, plus the materials strength evaluation performed by Materials and Processes Laboratory, led to the conclusion that the failed canopy was not substandard, and that its failure was not due to substandard structural capability reacting to "expected" loads. Further study of the 120 and 180 in. 70mm film convinced us that the parachute failure was initiated by the skewed frustum causing physical contact with the main parachute canopy flotation. This contact caused violent float dynamics which waterfalled into the canopy failure. The complete failure sequence is shown in Table 4 [4].

To gain an understanding of what one chute out means in terms of risks of losing an SRB, we performed a risk assessment for STS-4. Ratioing early estimates (using predicted main parachute angles of 15 deg radial, 24 deg tangential), load calculations showed a bolt tension of 168 kips. This compares with actual test data that showed the separation nut fails at 187 kips. However, film analysis showed that the actual main parachute pull angles were 13.3 deg radial and 14.9 deg tangential. These smaller angles equate to a bolt tension of 149 kips. This bolt tension capability means the separation nut would fail at a main parachute load of 272 kips at these angles. Figures 9 and 10 show this data. A complete damage assessment of all STS-3 Decelerator Subsystem hardware, both on A11 and A12, was performed to discern if any trends were evident and to establish preliminary refurbishment estimates. This data is shown in Figure 11 and revealed no significant trends.

Going back and relooking at STS-1 film (we could not see all of mains deployment on STS-2 film because of cloud cover), revealed that STS-1 also experienced the wake overtake phenomena (Fig. 12). We compared aerodynamic data from STS-1, STS-2, and STS-3 to see if any trends could be determined that could be used to predict this phenomena. Table 5 shows a listing of the aerodynamic parameters at the time of Decelerator Subsystem deployment. No trends could be developed from this data since it appears to be random.

Since it is not possible to change the drogue parachute design to reduce the wake turbulence overtake effects, and it is concluded that this disturbance will randomly occur during the Space Shuttle program, corrective actions, or options, were established for the near term and long term. Table 6 shows these options and their rationale.

The failure analysis, conclusions, and recommendations are shown in Figure 13. We believe that the incorporation of these recommendations will minimize the possibility of losing a parachute on future flights. On STS-4, 5, and 6, the canopy flotation has been removed and the main parachutes will remain attached to the SRB, by one attach point, after water impact to provide for retrieval access. Starting with STS-7, it is planned to incorporate a smoothing liner in the main parachute bag canopy flaps. Also, smoothing the frustum interior from the deployment bag exit plane to the frustum exist plane, attaching floats to the main parachute attach fittings (releasing parachutes at SRB water impact), and lowering the main parachute bags in the frustum are options being studied for STS-7 and subsequent Space Shuttle launches.

DATA AVAILABLE – A12

FLIGHT HARDWARE – MAIN PARACHUTES S/N 2066 AND 2067

70mm FILM COVERAGE (TRACKING SHIP)

- 50 in. LENS – “SMALL IMAGE”
- 120 in. LENS – “GOOD COVERAGE, NO WATER IMPACT”
- 180 in. LENS – “GOOD COVERAGE, INTERMITTENT FOCUS PROBLEM”

RADAR TRACK DATA

FLIGHT RECORDER DATA

- PARACHUTE LOADS
- EVENT TIMES
- ACCELERATIONS
- RATES

ATMOSPHERIC DATA

Figure 1. STS-3 data base.

EVALUATION SUMMARY

WATER IMPACT VELOCITY

- PREDICTED – 3 MAINS = 89 ft/sec \pm 6
2 MAINS = 113 ft/sec
- A11 (3 MAINS) – TBD (ALL DATA \approx NOMINAL)
- A12 (2 MAINS) – 110 ft/sec (PRELIM RADAR/PHOTO)

PARACHUTE LOADS (KIPS)

● DROGUE		PREDICTED			ACTUAL		
		<u>MIN</u>	<u>NOM</u>	<u>MAX</u>	<u>A11</u>	<u>A12</u>	
	1ST PEAK	117	160	294	274	160	
	2ND PEAK	191	234	303	281	245	
	3RD PEAK	231	272	328	307	292	
A11	● MAINS	<u>MIN</u>	<u>NOM</u>	<u>MAX</u>	<u>2062</u>	<u>2064</u>	<u>2063</u>
	1ST PEAK	75	98	120	102	98	85
	2ND PEAK	107	146	197	104	159	144
	3RD PEAK	97	142	182	98	136	115
A12		<u>MIN</u>	<u>NOM</u>	<u>MAX</u>	<u>2065</u>	<u>2067</u>	<u>2066</u>
	1ST PEAK	75	98	120	90	111	110
	2ND PEAK	107	146	197	181	FAILED	233
	3RD PEAK	97	142	182	180	FAILED	193

HARDWARE INSPECTION SUMMARY

- NO REEFING LINE CUTTER ANOMALIES
- A11 – DROGUE – MINIMAL DAMAGE
3 MAINS – MINIMAL DAMAGE – ALL FLOATS INTACT, ONE = SIGNIFICANT DAMAGE
- A12 – DROGUE – MINIMAL DAMAGE
MAINS – S/N 2065 – LOST (SANK) – ONE SIDE FLOAT SEGMENT RETRIEVED
S/N 2066 – MINIMAL DAMAGE – FLOAT MINIMAL DAMAGE
S/N 2067 – FAILED CANOPY – FLOAT MISSING WHEN RETRIEVED,
FLOAT SEGMENTS RETRIEVED SEPARATELY

Figure 2. STS-3 flight evaluation data.

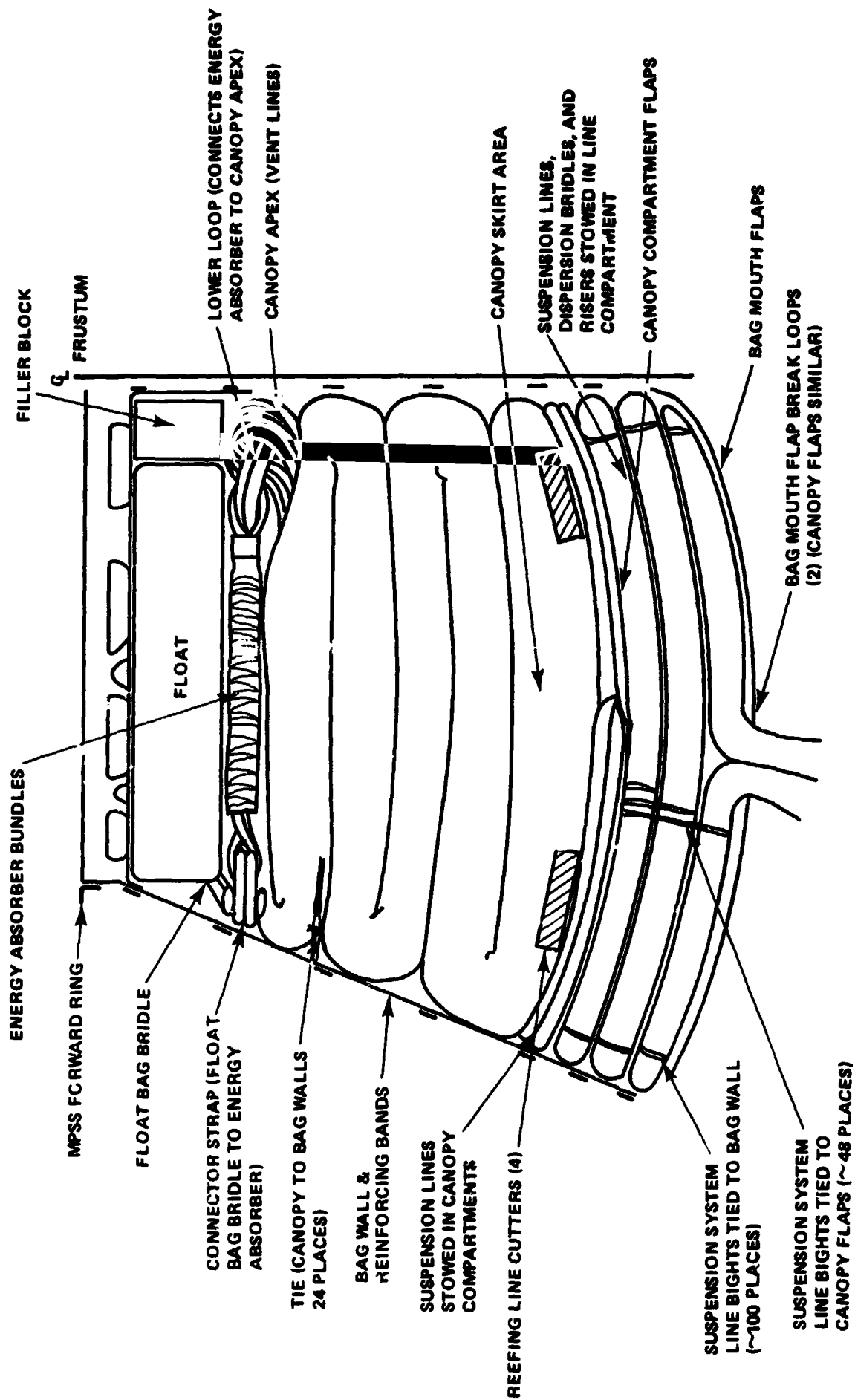


Figure 3. Packed main parachute - cross section.

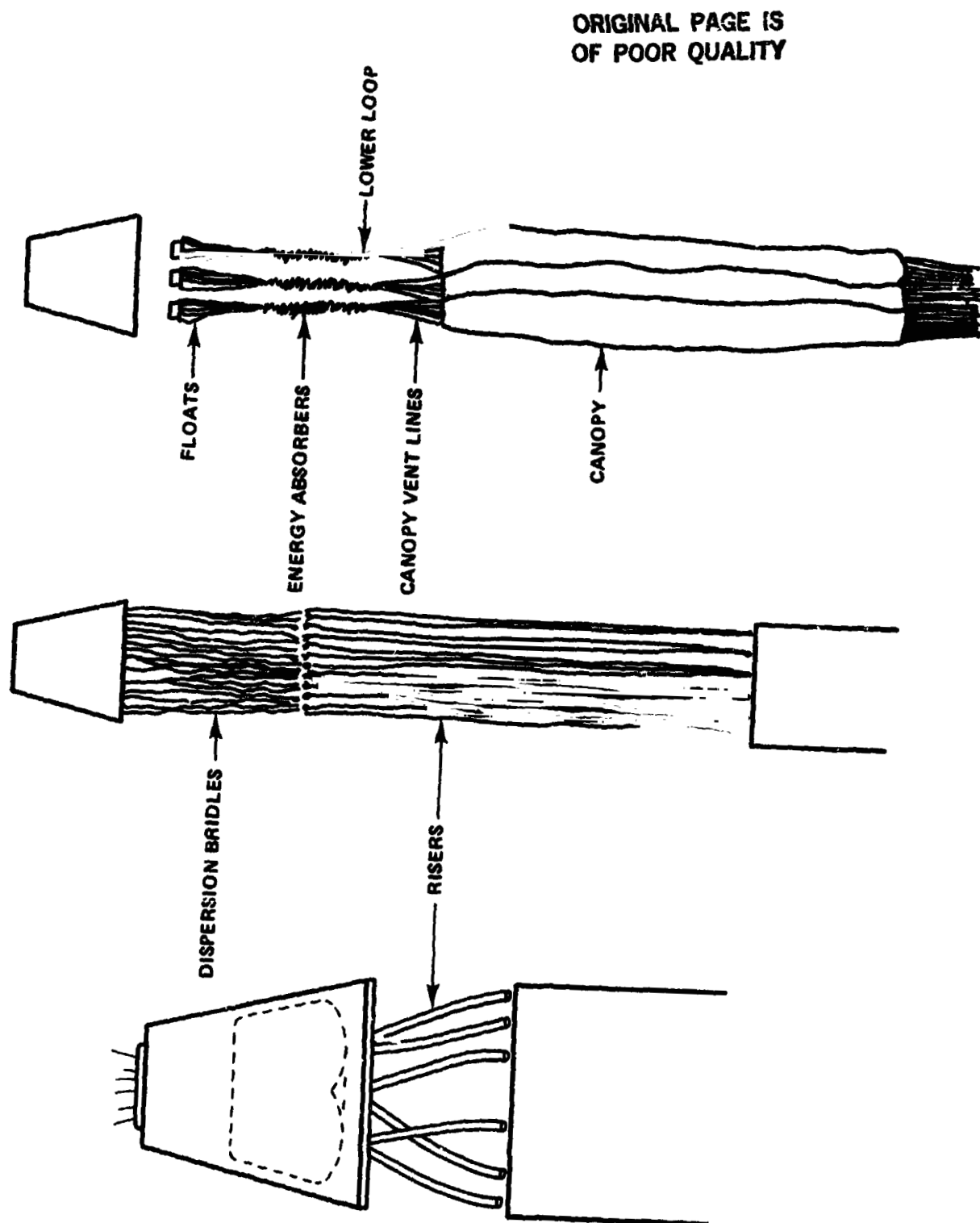
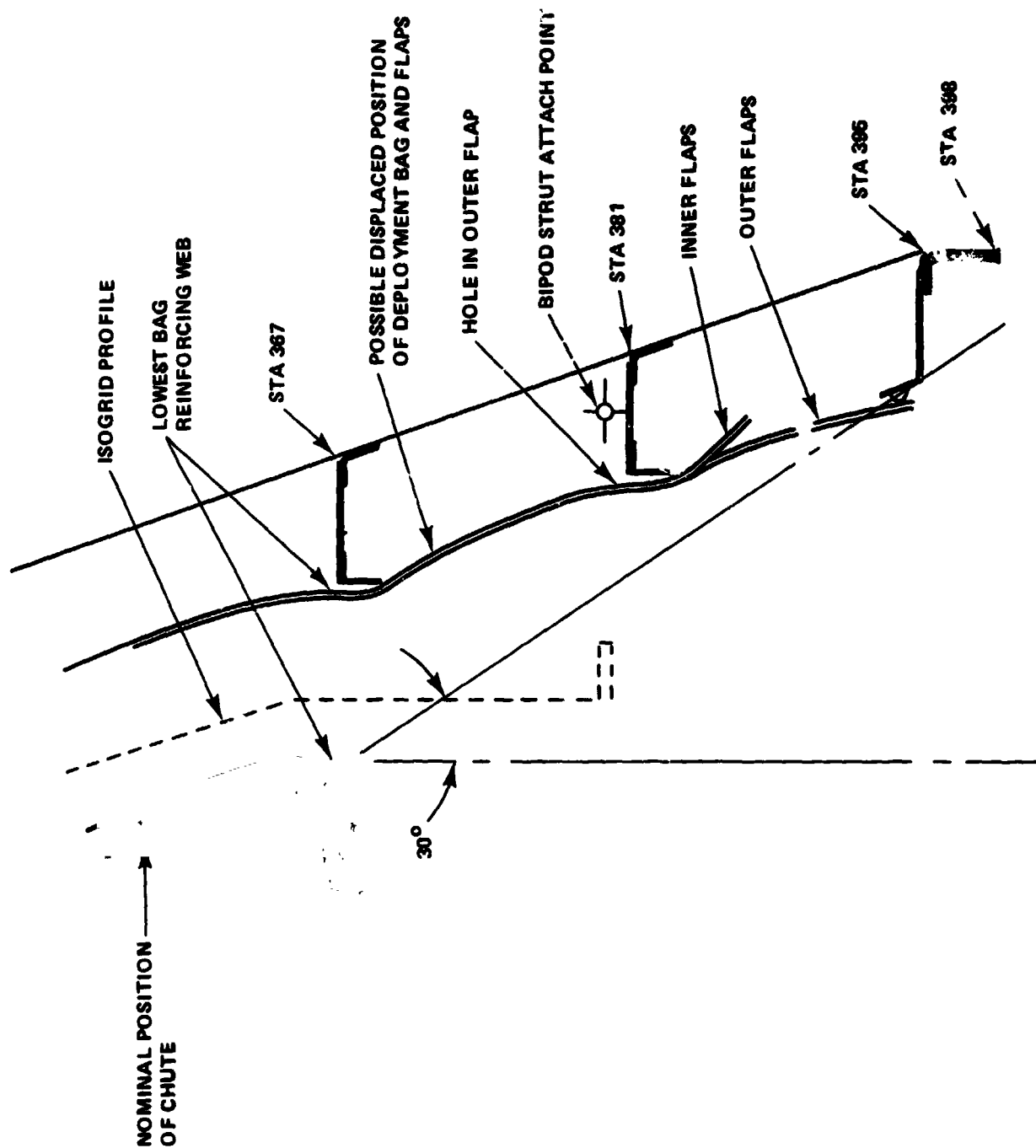


Figure 4. Idealized deployment sequence.

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Deployment bag and frustum structure.

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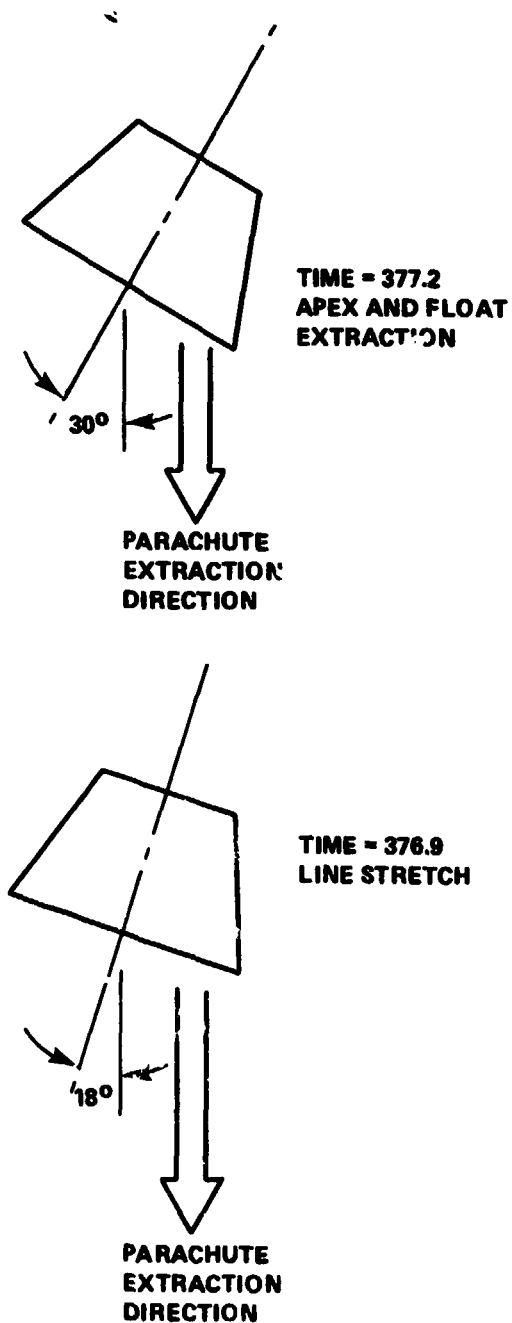


Figure 6. Frustum orientation during STS-3 parachute deployment.

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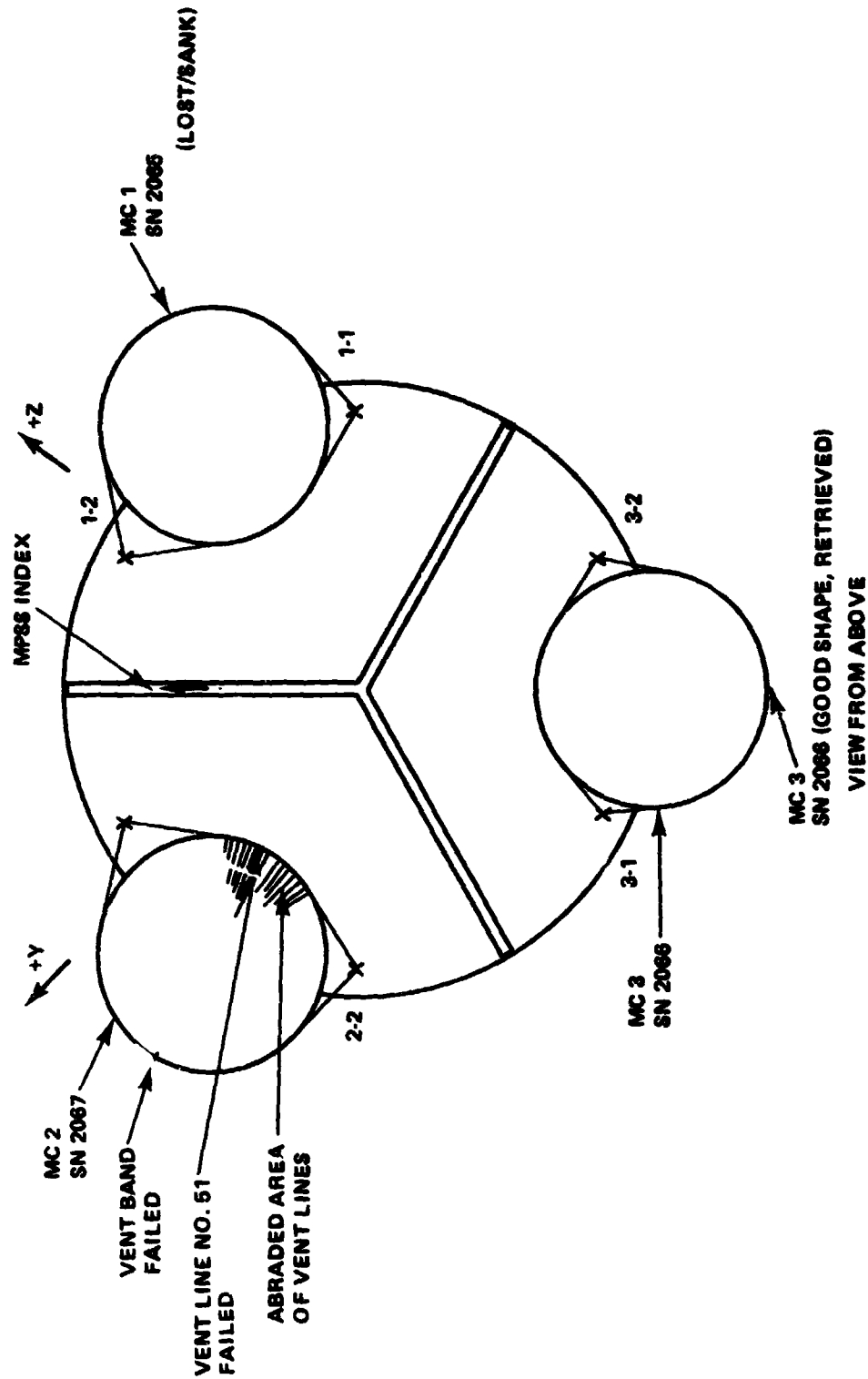


Figure 7. STS-3, A12 SRB parachute locations.

- FLOTATION MISSING WHEN RETRIEVED.
- MINIMUM VISUAL EVIDENCE OF CONTACT IN A12 FRUSTUM.

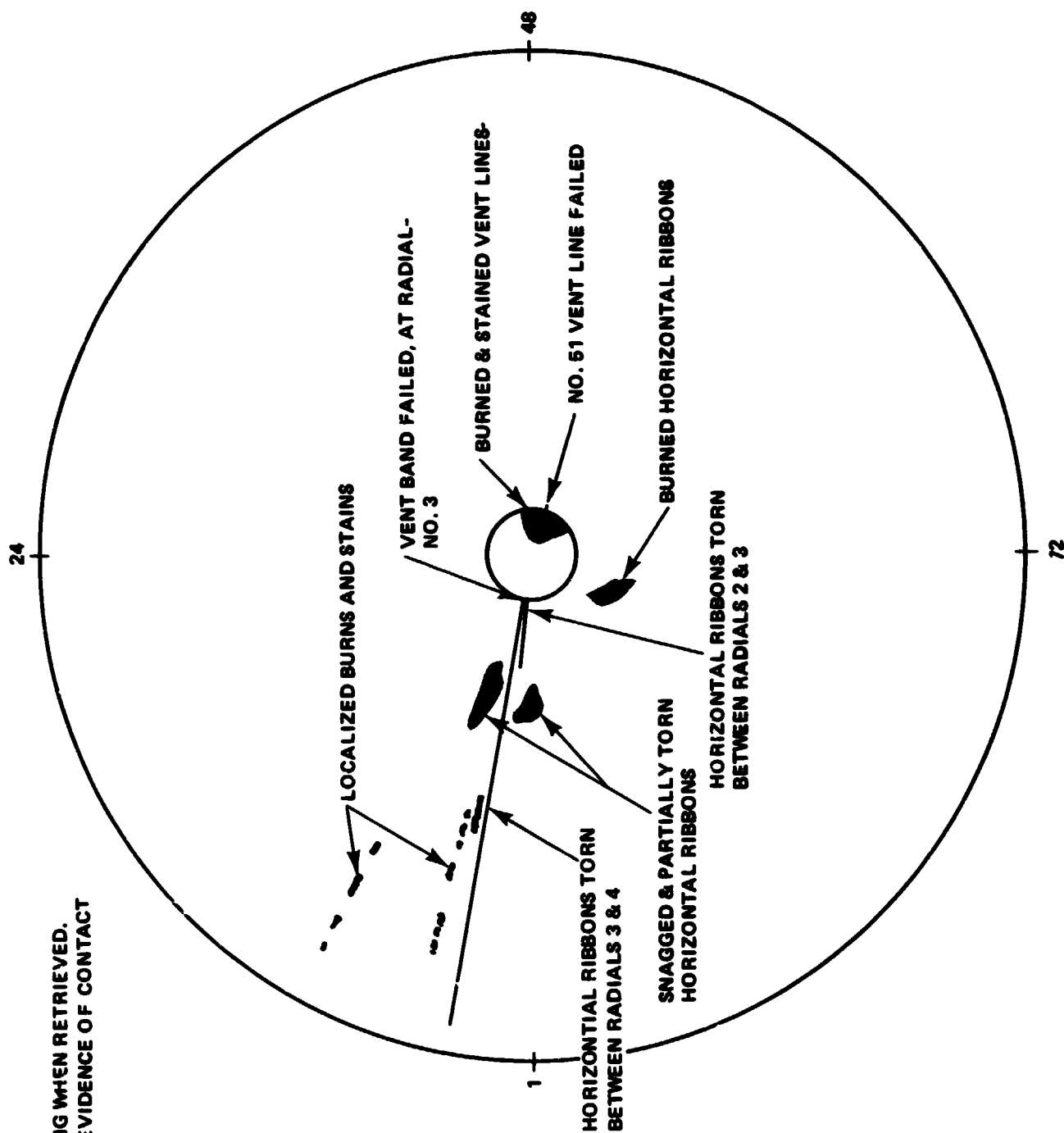


Figure 8. Significant damage areas, S/N 2067.

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MAIN PARACHUTE SEPARATION NUTS (A12)

<u>NUT SERIAL NO.</u>	<u>MAIN CHUTE NO.</u>	<u>REFERENCE DESIGN NO.</u>
000 30	1-1	X31F8
000 35	1-2	X31F9
000 36 (STAYED ATTACHED)	2-1	X31F10
000 38	2-2	X31F11
000 39	3-1	X31F12
000 40 (HIGH LOAD – 120 KIPS)	3-2	X31F13

EP42 BOLT TENSION ESTIMATE FOR A12 3-2 (BASED ON BOLT TENSION CALCULATIONS FROM ED22 STS-3 ATTACH PT. LOADS)

$$\frac{151,301 \times 120,000}{108,135} = 167,902 \text{ lb}$$

MORE LIKELY BOLT TENSION ESTIMATE (BASED ON STS-3 OBSERVATION AND CALCULATED RADIAL AND TANGENTIAL ANGLES OF 13.3 AND 14.9 DEG RESPECTIVELY)

FOR 120 KIP FITTING LOAD $T_{\text{bolt}} = 149,000 \text{ lb}$

**ASSUMING BOLT ULTIMATE OF 187,000 lb
EACH ATTACH POINT COULD TAKE $\approx 150,000 \text{ lb}$ (CHUTE LOAD OF 272,000 lb)**

Figure 9. A12 separation nut locations and load calculations.

MAIN PARACHUTE PEAK LOADS (KIPS) – ONE CHUTE FAILS AT 1ST INFLATION

	<u>STS-3 ACTUALS</u>			<u>STS-4 PREDICTED DISPERSED</u>		
	<u>2065</u>	<u>2067</u>	<u>2068</u>	<u>CHUTE 1</u>	<u>CHUTE 2</u>	<u>CHUTE 3</u>
1ST PEAK	94	111	114	127	99	99
2ND PEAK	185	FAILED	235	266*	FAILED	197
3RD PEAK	181	FAILED	194	260	FAILED	163

*AT MAX PREDICTED STS-4 LOAD: MAIN PARACHUTE SAFETY FACTOR REMAINING =
1.18 (REQ'T = 1.50, STS-3 PREFLIGHT = 1.39)
SEPARATION NUT SAFETY FACTOR REMAINING =
1.03 (REQ'T = 1.25, STS-3 PREFLIGHT = 1.09)

MAIN CHUTE MAXIMUM CAPABILITY – ASSUMING USED CHUTES

MAXIMUM FAILING LOAD = 338 KIPS (NO TEST VERIFICATION)
NO SAFETY FACTOR REMAINING

MAIN CHUTE SEPARATION NUT CAPABILITY – PULL ANGLES FROM STS-3 FILM

MAXIMUM FAILING LOAD = 150 KIPS/FITTING (FROM TEST DATA)
EQUIVALENT PARACHUTE LOAD = 272 KIPS WITH 10 PERCENT LOAD ASYMMETRY.

IMPLIES SERIOUS CONCERN FOR LOSS OF SRB

Figure 10. STS-4 risk assessment.

SRB-DSS STS-3 PARACHUTE CONDITION

- SRB A11
- ALL CHUTES RECOVERED:
MAINS S/N 2062, 2063, 2064
DROGUE S/N 1029
- SRB A12
- ONLY TWO MAIN CHUTES RECOVERED:
S/N 2066 DAMAGED DURING RETRIEVAL
S/N 2067 EXTENSIVE IN-FLIGHT DAMAGE
- DROGUE S/N 1030:
MINOR DAMAGE

MAIN CHUTE S/N 2067 DAMAGE SUMMARY

FLOAT DAMAGE

- FLOAT SEPARATED FROM CANOPY BEFORE RETRIEVAL
- BOTH SIDE FLOATS SEPARATED FROM CENTER FLOAT
- FLOAT BAG BRIDLE LEGS PULLED AWAY FROM SIDE FLOATS (COMPLETE WITH ADD ON REINFORCING WEBS – TCTI B-52-5257-01)
- CENTER FLOAT BAG TORN WHERE SIDE FLOAT BRIDLE LEGS CROSS BOTTOM SURFACE
- PLA CAVITY FILLER AND CENTER FLOAT BRIDLE LEGS INTACT
- EXTENSIVE FRICTION BURN ON OUTBOARD END OF CENTER FLOAT
- ENERGY ABSORBER STROKE TYPICAL OF OTHER UNITS (STS-1, STS-2, AND STS-3)
- LOWER LOOP CONNECTING ENERGY ABSORBER TO CANOPY APEX NOT RECOVERED
- SEVERE BURNING INSIDE ENERGY ABSORBER LOWER END LOOP (ONE PLY). NO BURNING ON UPPER END LOOP

VENT AREA DAMAGE

- VENT BANDS SEVERED AT RADIAL NO. 3
- VENT LINE NO. 51 SEVERED, 3 in. FROM VENT BAND (CONTINUATION OF VENT LINE NO. 3)
- SEVERE ABRASION OF VENT LINES, GORES 42 THROUGH 59. ABRADED VENT LINES SHOW GREEN COLOR ON INSIDE OR OUTSIDE SURFACES
- BROKEN STITCHES IN VENT LINE JOINT GORES 48, 47, 43, AND 42

CANOPY DAMAGE

- VENT BAND FAILED IN VENT BAND/RADIAL INTERSECTION AT RADIAL NO. 3. TYPICAL TENSION FAILURE INDICATED. NO EVIDENCE OF CONTACT ON OUTSIDE OF VENT BAND
- 250 HORIZONTAL RIBBONS SEVERED IN GORE BETWEEN RADIALS 3 AND 4
- 34 HORIZONTAL RIBBONS SEVERED IN GORE BETWEEN RADIALS 2 AND 3
- HORIZONTAL RIBBONS SNAGGED AND PARTIALLY TORN, GORES 96 THROUGH 6, RIBBONS 30 THROUGH 60
- HORIZONTAL RIBBONS WITH BURNS, GORES 75 THROUGH 81, RIBBONS 8 THROUGH 20
- HORIZONTAL RIBBONS WITH BURNS AND O/D THREAD FRAGMENTS, GORES 4 AND 5, RIBBONS 86 THROUGH 99
- MISCELLANEOUS BURNS, SNAGS, PARTIALLY TORN RIBBONS DISTRIBUTED OVER REST OF CANOPY

DEPLOYMENT BAG

- TEFLON CLOTH LINER PULLED AWAY, OUTBOARD ARC OF BAG
- FRICTION BURN ON CANOPY FLAP NO. 4, INSIDE SURFACE, HOLE THROUGH FLAP
- CANOPY FLAP NO. 8 TORN FROM BOTTOM END 22 in. (OF 35 in.)
- LOCAL FRICTION BURNS ON CANOPY FLAPS 5, 6, 7, AND 8
- FRICTION BURN AND HOLE ON BAG MOUTH FLAP NO. 4, INSIDE SURFACE

MAIN CHUTE S/N 2066 (A12) DAMAGE SUMMARY

- 16 HORIZONTAL RIBBONS TORN IN GORES 5 AND 6 NEAR VENT (POSSIBLE RETRIEVAL DAMAGE)
- 19 HORIZONTAL RIBBONS TORN IN GORE 53 NEAR SKIRT (OBSERVED SNAGGING ON STERN ROLLER, UTC LIBERTY)

Figure 11. STS-3 parachute subsystem damage assessment.

- NUMEROUS SMALL BURNED HOLES IN CANOPY. MANY BURNED FROM OUTSIDE
- NO OTHER SIGNIFICANT DAMAGE OR DISCOLORATION EXCEPT FOR DINGY GRAY APPEARANCE IN TOP OF CANOPY
- FLOAT ASSEMBLY AND ENERGY MODULATOR ATTACHED TO CANOPY AND IN GOOD CONDITION
- PLASTIC STRIP ENTANGLED IN VENT LINES (POSSIBLY FROM FRUSTUM LSC)
- 550 lb NYLON CORD ENTANGLED IN 2 RISERS (CORD OF TYPE NOT USED IN ASSEMBLY OR PACKING OF CHUTES)
- BAG MOUTH PULL LOOPS ON RISERS HAVE BROKEN STITCHES
- ALL 4 REEFING LINE CUTTERS FIRED
- CARGO LINKS NOT CADMIUM PLATED

DROGUE CHUTE S/N 1030 (A12) DAMAGE SUMMARY

- WEAVE SEPARATION ON 11 RADIAL EXTENSIONS (LESS SEVERE THAN ON STS-1 OR STS-2)
- POCKET BAND STITCHES BROKEN
- 5 POCKET BANDS LOOSE, ONE END
- DAMAGE AND BLACK DISCOLORATION AT LOWER END OF SUSPENSION LINE GROUPS NEAR WRAP (POSSIBLE CONTACT WITH BSM COVERS OR POWER BLOCK)
- ALL REEFING LINE CUTTERS FIRED

MAIN CHUTE S/N 2062 (A11) DAMAGE SUMMARY

- CHARRED PIECE OF LAMINATE MATERIAL (ABOUT 2 IN. SQUARE) FUSED INTO HORIZONTAL RIBBONS (POSSIBLY FROM ENGINE NOZZLE)
- NUMEROUS OTHER PIECES OF LAMINATE THROUGHOUT CANOPY
- NO SIGNIFICANT DAMAGE OR DISCOLORATION IN VENT AREA
- FLOAT ASSEMBLIES ATTACHED TO CANOPY AND IN GOOD CONDITION
- BAG MOUTH PULL LOOPS ON RISERS HAVE BROKEN STITCHES
- ALL 4 REEFING LINE CUTTERS FIRED. CUTTER ACTUATION LANYARD BROKEN AND SEAR MISSING

MAIN CHUTE S/N 2063 (A11) DAMAGE SUMMARY

- 10 HORIZONTAL RIBBONS TORN IN GORES 71 AND 72 IN MIDDLE OF CANOPY
- NO SIGNIFICANT DAMAGE OR DISCOLORATION IN VENT AREA
- CHARRED LAMINATE MATERIAL FUSED INTO HORIZONTAL RIBBONS, GORE 58, NEAR SKIRT
- 2 STRIPS OF PLASTIC ENTANGLED IN ENERGY ABSORBER AND CANOPY (POSSIBLY FROM FRUSTUM LSC)
- LOWER CUTTER RETENTION LOOP BURNED, GORE 24 (POSSIBLY FROM STRIP OUT OF 2ND STAGE REEFING LINE)
- ALL 4 REEFING LINE CUTTERS FIRED
- FLOAT ASSEMBLY CONNECTED TO CANOPY AND IN GOOD CONDITION

MAIN CHUTE S/N 2064 (A11) DAMAGE SUMMARY

- LOWER CUTTER RETENTION LOOP BURNED, GORE 24 (POSSIBLY FROM STRIP OUT OF 2ND STAGE REEFING LINE)
- SUSPENSION LINE NO. 96 PARTIALLY TORN, 3 ft FROM SKIRT
- NO SIGNIFICANT DAMAGE OR DISCOLORATION IN VENT AREA
- FLOAT ASSEMBLY ATTACHED TO CANOPY AND IN GOOD CONDITION
- NUMEROUS PIECES OF LAMINATE MATERIAL THROUGHOUT CANOPY
- BLACK DISCOLORATION WITH BURNED EDGES ON ONE RISER – 10 ft FROM LOWER END
- ALL 4 REEFING LINE CUTTERS FIRED

DROGUE CHUTE S/N 1029 (A11) DAMAGE SUMMARY

- MINOR WEAVE SEPARATION ON 15 RADIAL EXTENSIONS (LESS SEVERE THAN ON STS-1 OR STS-2)
- POCKET BAND STITCHES BROKEN
- 10 POCKET BANDS LOOSE, ONE END
- ALL 4 REEFING LINE CUTTERS FIRED

Figure 11. (Concluded)

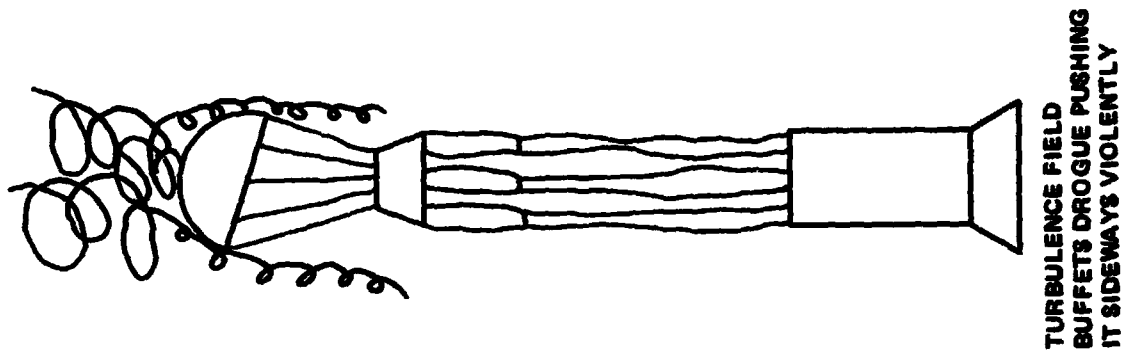
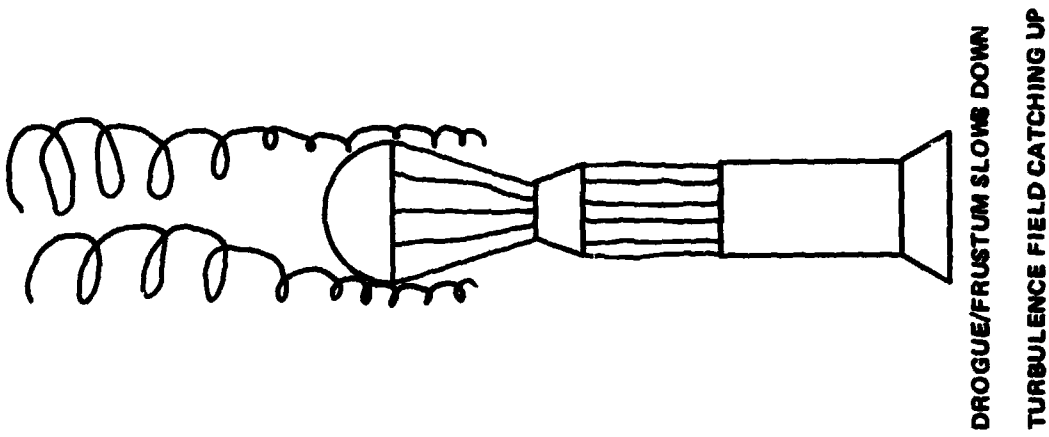
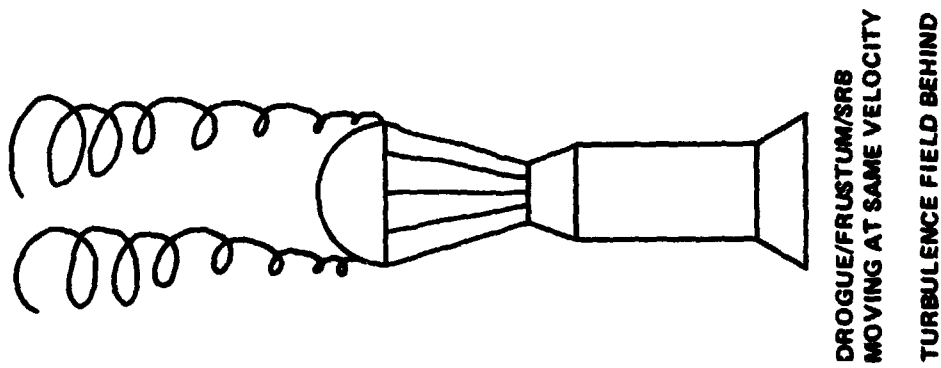


Figure 12. Wake turbulence overtake phenomena.

FAILURE DUE TO A COMBINATION OF:

- **LARGE FRUSTUM ANGLE AT TIME OF PARACHUTE DEPLOYMENT**
- **CANOPY AND/OR FLOTATION CONTACT WITH FRUSTUM**
- **FLOTATION TO FLOTATION CONTACT OR ENTANGLEMENT**

CORRECTIVE ACTIONS RECOMMENDED

- **ELIMINATE APEX FLOTATION DESIGN**
- **INCORPORATE "SMOOTHING" LINER IN DEPLOYMENT BAG CANOPY FLAPS**
- **FRUSTUM CONTACT ISSUE**
 - **BEST SOLUTION – MOVE FRUSTUM SEPARATION PLANE \approx 2 ft FORWARD**
 - **ALTERNATE SOLUTION**
 - **FAIR (SMOOTH) FRUSTUM INTERIOR FROM DEPLOYMENT BAG EXIT TO FRUSTUM EXIT PLANE**
 - **LOWER MAINS DEPLOYMENT BAGS AS MUCH AS POSSIBLE (6-11 in.)**
- **PROVIDE FLOTATION VIA: (1) LEAVE ATTACHED TO BOOSTER
(2) FLOAT VIA DECK FITTING FLOTATION**

FLIGHT EFFECTIVITY

- **STS-4/SUBSEQUENT – DISCONNECT APEX FLOTATION AND LEAVE PARACHUTES ATTACHED TO BOOSTER**
- **ASAP – IMPLEMENT SOLUTION TO FRUSTUM CONTACT ISSUE**

REQUEST KSC RECOMMENDATIONS FOR RETRIEVING

- **PARACHUTES ATTACHED TO THE BOOSTER**
- **PARACHUTES RELEASED, FLOATING VIA DECK FITTING FLOTATION**
- **OTHER**

Figure 13. Team conclusions/recommendations.

TABLE 1. STS-3 PARACHUTE ANOMALY TEAM MEMBERS

MEMBERS	
MSFC	- R. Runkle, EP14
	K. Henson, EE11
	D. Kross, ED 22
	S. Reed, EG 22
	D. Bacchus, ED 32
	R. Nichols, EH34
	W. Coiner, EP42
MMC	- D. Moog
	B. Woodis
	F. Tallentire
PPC	- B. Rodier
	T. Metz
SANDIA	- Dr. D. Wolf
	I. Holt

TABLE 2. TEAM TASK ASSIGNMENTS

Vandenberg Film Assessment	Dave Bacchus/ED 32
Parachute Hardware Damage	Frank Tallentire/MMC
Interface Hardware Damage	Roy Runkle/EP14
Parachute/SRB Geometry	Frank Tallentire/MMC
Potential STS-4 Risks	Dick Moog/MMC
Corrective Action Options	Roy Runkle/EP14
Nylon Material and Joint Strength	Bob Rodier/PPC
Cano Analysis	Dean Wolf/SANDIA
Failure Scenario	Bill Woodis/MMC
Loads Definition	Denny Kross/ED 22

TABLE 3. S/N 2067 MATERIAL HISTORY

Material and Fabrication History

Material on both canopies came from same lot of material.

All finished dimension measurements in specification after fabrication.

No fabrication anomalies noted in crown area on fabrication travelers.

Minor anomalies noted for lower canopy on fabrication travelers. (All anomalies dispositioned per standard shop processes)

Basic materials information.

	MIL Spec	P.O. Number (Pioneer)	Receiving Inspection Tests	
			Low	Average
Vent Band 4000 lb	MIL-T-5608 TY 6 CLE	56395	4500 lb	4912 lb
Vent Line 6000 lb	MIL-W-27657 TY 3	56389	6980 lb	7210 lb
Upper Horiz. 1000 lb	MIL-T-5603 TY 2 CLE	56393	1180 lb	1219 lb
Lower Horiz. 460 lb	MIL-T-5608 TY 2 CLD	56392	492 lb	533 lb

TABLE 4. A12 MAIN PARACHUTE FAILURE SEQUENCE

Event	Supporting Evidence
<ol style="list-style-type: none"> 1. Large deployment angle. 2. Large deployment angle damaged float and initiated violent float dynamic activity. 3. Rotation system from chutes 1 and 2 become temporarily entangled placing large lateral loads on vent. 4. Vent line No. 51 fails at a chute load of 110,000 lb. 5. Dynamic unloading of the broken radial caused a failure to propagate along nearly the entire length of gore three. 	<p>Flight photographs.</p> <p>Photo examination shows three float segments separated from cluster.</p> <p>Only center segment attached to bridles at retrieval.</p> <p>Photos show violent float dynamics.</p> <p>Extensive burn marks and green stain on vent lines, gore 43 through 58.</p> <p>Stitch failure on vent lines gore 48 and 49.</p> <p>Extensive burning on lower loop of energy absorber.</p> <p>Center float assembly not attached to chute at retrieval.</p> <p>Energy absorber strokes at 8,000 to 12,000 lb. This could cause failure or damage to one ply of attach loop.</p> <p>Load cell data.</p> <p>Inspection of failed hardware.</p> <p>CANO analysis and strain energy calculations show sufficient strain energy would exist to fail the entire gore, which very nearly did happen.</p>

TABLE 5. STS-1, 2, AND 3 PARACHUTE SUBSYSTEM AERODYNAMIC PARAMETERS

STS -	SRB		t (sec)	h (ft)	V Rel. (ft/sec)	q (lb/ft ²)	V _{wind} (ft/sec)	γ Rel. (deg)	SRB Rates (deg/sec)		
									Pitch	Yaw	Roll
1	LH	A07	391.591	N/A	N/A	N/A	15	N/A	1	6	>>20
	RH	A08	393.840	6529	359	122	15	-85	1	6	>>20
2	LH	A09	377.512	6158	354	121	36	-81	N/A	N/A	N/A
	RH	A10	379.197	6295	357	122	36	-86	1	2	4
3	LH	A11	369.250	6415	354	120	41	-85	3	0.2	13
	RH	A12	375.45	6332	359	123	41	-84	2	0	14
4	LH	A13									
	RH	A14									
5	LH	A15									
	RH	A16									
6	LH	A17									
	RH	A18									

N/A - Data not available.

TABLE 6. POSSIBLE CORRECTIVE ACTIONS/OPTIONS

ACTION	RATIONALE
<p>FLOTATION</p> <ol style="list-style-type: none"> 1. Do nothing. 2. Remove/deactivate floats. Leave mains attached at impact. (Deactivate sep. nuts). 3. Redesign main float, leave @ Apex (i.e., make smaller and/or change attach concept.) 4. Attach floats to attach fittings. 	<p>New float design - STS-4/subsequent. Lack of positive evidence. Low risk \approx 1:18 and probability of SRB survival with 2 chutes.</p> <p>Floats would not hang up or tangle during extraction. Retrieval personnel would release cargo links during retrieval operation. Preliminary retrieval personnel concurrence obtained.</p> <p>Reduce load in canopy by size reduction. Make float attach points non-structural members (i.e., sacrificial).</p> <p>Floats would not interfere with deploy- ment. Parachutes will float canopy down.</p>
<p>FRUSTUM</p> <ol style="list-style-type: none"> 1. Raise frustum separation plane. 2. Smooth out inside surface of frustum and/or lower main bags as soon as practical. 	<p>Eliminates hard structure for potential contact when parachutes exit deployment bags.</p> <p>Reduce deployment damage by providing a smooth surface and reduce likelihood of contact.</p>

REFERENCES

1. STS-3 Parachute Anomaly Team Task Reports, Letter EP14-(82-35), dated June 11, 1982.
2. Main Parachute S/N 2067, Materials Test Report, Letter EH34-(82-17), dated June 14, 1982.
3. AIAA-81-1922, Paper Entitled, 'Theoretical Analysis of Wake-Induced Parachute Collapse.'
4. Main Parachute S/N 2067, Failure Sequence, Sandia Letter, SNL 1312, dated June 10, 1982.

APPROVAL

STS-3 MAIN PARACHUTE FAILURE

By Roy Runkle and Keith Henson

The information in this report has been reviewed for technical content. Review of any information concerning Department of Defense or nuclear energy activities or programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.



A. A. McCOOL

Director, Structures and Propulsion Laboratory